Creative Goal Modeling for Innovative Requirements

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Abstract

[Context] When determining the functions and qualities (a.k.a. requirements) for a system, creativity is key to drive innovation and foster business success. However, creative requirements must be practically operationalized, grounded in concrete functions and system interactions. Requirements Engineering (RE) has produced a wealth of methods centered around goal modeling, in order to graphically explore the space of alternative requirements, linking functions to goals and dependencies. In parallel work, creativity theories from the social sciences have been applied to the design of creative requirements workshops, pushing stakeholders to develop innovative systems. Goal models tend to focus on what is known, while creativity workshops are expensive, require a specific skill set to facilitate, and produce mainly paper-based, unstructured outputs. **[Objective]** Our aim in this work is to explore beneficial combinations of the two areas of work in order to overcome these and other limitations, facilitating creative requirements elicitation, supported by a simple extension of a well-known and structured requirements modeling technique. **[Method]** We take a Design Science approach, iterating over exploratory studies, design, and summative validation studies. **[Results]** The result is the Creative Leaf tool and method supporting creative goal modeling for RE. **[Conclusion]** We support creative RE by making creativity techniques more accessible, producing structured digital outputs which better match to existing RE methods with associated analysis procedures and transformations.

Keywords: Requirements Engineering, Creativity, Goal Modeling

1. Introduction

In order to understand the complex space of systems requirements, including Information Systems, Requirements Engineering (RE) has often turned to conceptual models, taking advantage of their powers of abstraction, communication, and analysis. Goal models have received much attention in Requirements

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Engineering (RE) for system analysis and design, (e.g., [1]), including Information and Software Systems Development (e.g., [2]), due to their ability to capture and reason over alternative possible requirements, analyzing and justifying decisions via links to goals, both functional and non-functional (see [3] for a recent map of Goal-Oriented Requirements Engineering (GORE)).

Despite the focus on GORE, practical challenges remain. Much work assumes the goal model as a starting point, while in practice it can be difficult for users to articulate their goals and to populate the model with content [1]. Often they are more comfortable speaking in terms of concrete tasks or system elements. As such, it can be difficult to fill models with content, especially for inexperienced modelers. As goal modeling involves a hierarchical process of either top-down refinement or bottom-up exploration, it often covers the known space of actions, intentions, or possibilities. As such, the content and alternatives captured in goal models are not necessarily creative, and are not likely to lead to more innovative systems.

A more recent line of requirements work has focused on the systematic use of creativity theories and techniques, mainly from the social sciences and psychology, in order to develop creative requirements for innovative systems, e.g., [4, 5, 6]. When providing requirements, stakeholders are often constrained by their past experiences and by what they think is technically possible. Explicit techniques are needed in order to push stakeholders to think outside their typical space, expanding the scope of their search.

Creativity techniques are often applied in the form of structured workshops [7]. Although workshops have been successful, they usually require a group of stakeholders to be fully present for multiple hours or days. The total cost is high, particularly when skilled stakeholders are involved. Furthermore, running a successful creativity workshop requires a considerable amount of soft skills, experience, and training. Although guidelines and a consideration of context can help ([6, 8, 6]) most of these skills are hard to learn without practical experience or training. Methods are needed to make creativity for RE more accessible.

Furthermore, the output of creativity techniques used in the workshops are usually captured on paper, are often unstructured (e.g., idea notes, post-its, storyboards, etc.), and must be manually translated to downstream artifacts (e.g., textual requirements, design specs). Past workshops have used Use Cases and Scenarios to capture and structure creative output, but such structures focus on functional and procedural paths. Such models were used in a lightweight way, not taking advantage of structured semantics, reasoning or decision-making power. Rationale for the rejection or acceptance of ideas was often lost.

In this work, we design and evaluate a tool and method, along with a simple language extension, which leverages the advantages of both goal modeling and creativity for RE, while addressing the aforementioned challenges. As we take a Design Science approach, our work is aimed to make improvements over a problem in order to achieve stakeholder goals [9, 10]. Specifically, following the Design Science Template from [9], we improve: *requirements discovery processes*, by: *providing a creative, goal model-based RE tool and method*, which satisfies the following requirements:

R1. Enhances or maintains current creative RE practices by:

[**R1a.**] Supporting the discovery of creative ideas,

[**R1b.**] without inhibiting creative flow,

[**R1c.**] capturing creative ideas in a simple extension to a well-known RE language, allowing for the possible use of existing RE techniques, potentially with adjustments or extensions (e.g., analysis [11] or transformations [12]), and

[**R1d.**] making creativity for RE more accessible.

R2. Enhances current RE goal modeling practices by capturing:

[**R2a.**] creative content in the model as part of a simple extension, as well as

[**R2b.**] increased typical content, supporting requirements completeness,

[**R2c.**] enhancing the utility of goal modeling.

in order to: *develop requirements which are both creative and strategic, being new to the organization and being in line with organizational goals, leading to innovative and successful systems.*

Aspects such as creativity, completeness, and utility are difficult to measure. In this work we measure progress towards our requirements using measures such as fluency (number of ideas), model size, expert evaluation of novelty and utility, and qualitative user impressions of the method.

Combining creativity techniques with structured modeling is challenging. Effective creativity relies on the presence of 'flow' and the uninhibited freedom to produce novel ideas [13]. Structured modeling, on the other hand, allows users to capture their ideas using predefined and regulated concepts and relationships, forcing one to model 'inside the box'. Combining these techniques requires a careful balance between freedom and structure, balancing design rationale along with the irrational – thus much attention must be paid to the design of the tool and method, leading us to adopt an iterative design method.

In this work we use a variety of example domains to iteratively evaluate and refine our approach. Some of these system domains are software-intensive, while some are more broad. Previous work has shown that both creativity techniques and goal modeling have a wide applicability to software-intensive and more general domains where solutions may or may not involve software[1]. As RE

[1] See example domains from the iStar Showcase [14], including software domains like healthcare monitoring systems and online counseling, and more general domains like public services and performance management for enterprises. In the area of creativity, techniques have been applied to software-intensive cases such as requirements for web services [15], and broader cases such as air traffic management and security access [7, 16]

focuses on understanding the problem (business needs), and not specifying the solution in a way that influences design [17], the neutrality of RE method results depending on the level of software involvement is not surprising. However, the majority of previous work has focused on the applicability of goal models and creativity (individually) to software-intensive systems. As such, although we use a range of examples in this work, we believe the combination of these techniques is particularly useful for systems where software can play a role, including information systems.

Preliminary and brief descriptions of parts of this work have appeared in workshop and poster papers. Papers [18, 19] describe initial ideas about combining creativity and goal modeling using historical case study examples, [20] describes results of the second (of six) design cycles, while [21] gives a brief description of the resulting tool.

Our paper is organized as follows. After providing more background on goal modeling and creativity in RE in Sec. 2, Sec. 3 describes our first iterations through the design cycle. We used insights from these early cycles to design the Creative Leaf tool and method (Sec. 4). We report on our most recent validation cycle, beginning to assess the satisfaction of our design requirements (Sec. 5). Sec. 6 discusses findings beyond our initial research questions and addresses threats to the validity of our validation cycle. We describe related work in Sec. 7, while Sec. 8 concludes the paper, describing plans for future work.

2. Background

2.1. Goal Modeling for Requirements Engineering

Several goal modeling languages exist, sometimes with internal variations. For this work we've used an early version of iStar 2.0 [22], an attempt to consolidate variations of the i* language. We do not believe that the specific type of goal model has much impact on creative output; iStar could be easily substituted for Tropos or GRL, or even the graphical part of KAOS (see [3] for information on other goal modeling approaches).

Standard i* consists of *Actors* (stakeholders or systems) and *intentions*: (clear-cut) *goals*, (qualitative) *softgoals*, *tasks*, and *resources*. Actors depend on each other for intentions, intentions are related to each other inside of actor boundaries: they are AND or OR *Refined*, and various alternatives can contribute qualitatively to softgoals using Makes/Helps/Hurts/Breaks *Contribution* links. Details on iStar (with slight variations) can be found in [23, 22]. An example iStar model as it appears in our implementation can be seen in the center of Fig. 3.

One of the benefits of the iStar-family of models is the ability to support qualitative or quantitative evaluation of alternatives [11, 24]. Given starting labels representing the level of satisfaction (or denial) of an element, such values can be propagated through model links to explore their affects over the model ("what if?").

Much work has been devoted to taking early requirements as captured in goal models and transforming or mapping them to downstream, more-detailed requirements and design artifacts (e.g, UML, business processes, textual requirements), see [12] for a survey of such methods. We believe the "early" RE nature of goal modeling [2] is a good fit with creativity, as opposed to more detailed "later" models such as process models or UML diagrams. To summarize, we select goal modeling, and iStar in particular, as a common RE language due to it's ability to capture design rationale, to align requirements with business objectives, to consider social aspects of requirements (stakeholders, dependencies), and to allow analysts to take advantage of the extensive body of GORE approaches [3, 11, 12].

However, goal models come with challenges: it's often difficult to populate such models with content in practice, and although widely studied in academia [3], goal models have not typically been adopted in industry [25]. However, we see that concepts and ideas from GORE have been included in recent Enterprise Modeling standards [26, 27]. Our tool and method helps to address adoption issues by providing methods to discover both creative and more familiar model content, and by demonstrating a practical use case for goal modeling in the support of creative RE. Further work should examine whether our general method can be applied with the same benefits to alternative, non-intentional models which are used more frequently in industry, e.g., UML, BPMN.

2.2. Creativity Approaches for Requirements Engineering

The past decade has seen the application of creativity techniques to RE. Maiden et al. adopt existing definitions of creativity to define creative requirements as those that are both novel and appropriate (useful) [4]. The Creative Problem Solving (CPS) method describes creativity as a divergence then convergence of ideas [28]. According to Boden, creativity can be classified under different types: 1) transformational, changing boundary rules to consider transformational ideas, possibly in another paradigm; 2) exploratory, exploring a space of possibilities; or 3) combinatorial, combining together creative output [29]. Poincaré describes four stages of the creative process: 1) preparation, understanding and collecting information; 2) incubation, reflection; 3) illumination, EUREKA! moments; and 4) verification, evaluating against criteria [30].

In this study, we have broadly investigated various types of creativity as part of our initial exploratory and formative cycles. In order to narrow our scope of measurement, our most recent validation cycle focuses on divergent creativity, leaving detailed exploration of convergent creativity to future design and validation cycles.

In practical terms, creativity is often applied in the form of *creativity activities*, semi-structured techniques which guide participants to think in new directions. The simplest and best-known creativity technique is Brainstorming. Other well-known techniques include Role playing and Prototyping. Less well-known techniques include Hall of Fame/Bright Sparks, where famous personas are used to generate ideas, and Pairwise Comparison, where ideas are paired and possibly combined. Creativity Triggers use experience gained via years of project work to present trigger words (service, connection, trust, etc.) including examples, to trigger new ideas about a domain [31]. The BeCreative site gives a helpful overview of selected creativity activities, classifying them by creativity type [32].

Outputs to creativity activities are “ideas”, typically captured on post-it (sticky) notes. Generally, ideas are descriptions of new desired functions or qualities related to the domain. An idea can be quite vague and high-level, and can thus be broken down into one or more requirements. The requirements may or may not be included in the final system requirements, depending on whether or not the idea and its associated requirements are eventually accepted or rejected.

Several papers have reported experience applying creativity techniques in an RE workshop setting as part of the RESCUE process (e.g., [7, 33]). This approach has been applied in settings such as Air Traffic Control, work-integrated learning (APOSDLE), and food traceability. Inputs to workshops included Use Cases, context, and rich picture models. Workshop outputs included collages using pictures, storyboards, idea cards placed on pin boards, and mock-ups. Outputs were converted, manually by analysts, into lists of ideas, requirements, and/or use cases. The nature of this output meant that rationale for decisions was lost, and excluded the use of any form of semi-automated analysis (e.g., [11]) or transformations (e.g., [12]).

Much effort has been placed on creativity support tools in the literature, e.g., [34]. Tools typically focus on supporting a particular creative activity, e.g., mind maps, composition of document pieces, Bright Sparks [35] or CRUISE creative search [36] (see [4] for a summary). Although individual tools are abundant, tools which guide participants in an overall creative process – candidates to replace the workshop structure – are lacking. We conduct a series of exploratory and formative studies in order to understand how creativity activities and their available supporting tools could work together to produce one cohesive, model-based output.

2.3. Design Science

Traditional, natural sciences focus on discovering and proving knowledge about the physical world, while other disciplines, including Information Systems and Software Engineering, focus on the design of artifacts with desired properties [37]. In the latter case, we employ systematic methods for building and evaluating artifacts and their properties, following a Design Science paradigm.

Design Science starts by identifying a relevant problem with research potential [37]. In our case, requirements must be creative, in order to meet the business drive for innovation [4], but must also be justified, avoiding solving problems/meeting needs which do not exist, or missing important problems or needs [2]. One can argue that truly innovative products create their own needs, e.g., did the average person know they needed a smartphone before they had one? Even in such cases, it is a useful exercise to be able to rationalize the innovation. The product or system is innovative for whom? Why?

The next steps of Design Science involve iteration through problem investigation, treatment design, and validation. In our case we perform a series of exploratory studies investigating how people use creativity techniques to come up with ideas, how people use goal models to capture such ideas, and how the modeling of ideas feeds back into the creative process. Such studies lead to an initial treatment design, which was iteratively validated and refined through further studies. Our final study focuses on a summative evaluation of our research questions.

3. Exploratory & Formative Design Cycles

We describe five exploratory and formative cycles of design and validation informing our tool and method design. Although our studies were exploratory, we were guided by a set of initial research questions (knowledge questions as per [9]):

IQ1. Are goal modeling and creativity techniques complementary? If so, how?

IQ2. How can goal modeling and creativity techniques work together to enhance both goal modeling and creative output?

IQ3. Do goal models help or constrain creativity?

IQ4. Can creative ideas be related back to the goal model? How?

IQ5. Do certain creativity activities perform better or worse than others when used with goal models?

Due to their exploratory and qualitative nature, the studies are mainly "single-case mechanism" rather than "statistical difference-making" experiments [9], i.e. we do not compare our findings against a baseline. For all studies, we recruited participants who have at least basic knowledge of goal modeling (covered

Cycle	Domain	Implementation	# Groups	Group Size	Duration (hours)	Total Participants	Participants
1	Air Traffic, Food Safety	Other tools	N/A	N/A	N/A	N/A	The researchers
2	Parking Garage	Paper	9	1-4	1	23	Undergrad & grad students at City, Univ. of London
3	Quantified Self App	Paper	5	2-4	1	16	Researchers at RE conference & Univ. of Toronto
4	Parking App	Paper & Tool	13	2-4	1	29	Undergrad & grad students at City, Univ. of London
5	Holiday Shopping App	Paper & Tool	5	2-3	2	11	Grad students & postdocs at Univ. of Trento
6	Garden Bridge	Tool	6	2	2	12	Grad students & postdocs at City, Univ. of London, Trento & Toronto

Table 1: Summary of Design and Validation Cycles

topic in one course semester), in order to focus our evaluation more on the tool and process and less on the usability of goal modeling. Participants for all cycles came from four groups: Bachelor's and Master's students studying a range of Information System-related topics at City, University of London (cycle 2, 4), graduate students and researchers at the University of Trento (Italy) with a technical and RE background (cycle 5, 6), graduate students and researchers at the University of Toronto (Canada) also with a technical and RE background (cycle 3, 6), international researchers attending the RE conference in Ottawa (Canada) with a technical background (cycle 3), and City, University of London students taking a Creativity-related Master's program (cycle 6).

Studies were facilitated by the first author, but after explaining the study setup and steps, her role was only observational, interjecting only when the groups were obviously stuck or when they asked her a question. Details of design and validation cycles, including participants and duration, when applicable, can be found in Table 1. Study material and raw results can be found at `https://tinyurl.com/cgmStudy` and in an online repository [38]. We describe Cycle 6, the first summative validation study, in Sec. 5.

3.1. Exploratory Cycles

Our first cycle of investigation and design focused on past City University project data, examining the problem context and developing early designs for integrating modeling as an input and/or output of creativity activities. We examined historical City, University of London study data from the APOSDLE work-integrated learning project, the TRACEBACK food safety project, and a project analyzing requirements for a Controlled Airspace Infringement Tool for the UK's national air traffic service. These projects had either used creativity techniques or goal modeling but had not used both techniques together. See [18, 19] for early examples resulting from the first design cycle, showing how creativity activities could be used with iStar.

Our second exploratory cycle examined students sketching a goal model on paper then applying a creativity technique to the same domain (or vice versa), in order to understand potential synergies between creativity techniques and goal models. We arranged nine one-hour sessions with small groups of 1-4 students, primarily graduate students, all of whom had some experience with iStar models through an RE course. Sessions involved a total of 23 student participants.

In the sessions, student were given a toy scenario involving app design for a parking garage, then were asked to sketch a goal model and come up with creative ideas guided by selected creativity triggers. Five groups performed goal modeling then creative thinking, while the other four groups did the reverse. Participants reflected on the process via a short questionnaire, including the ordering of activities and potential synergies between modeling and creative thought. All questionnaires, study instructions and raw data can be found at `https://tinyurl.com/cgmStudy` and [38] under "Exploratory Studies" (Cycle 1 and 2). Further details of this exploratory study are reported in [20].

3.2. Formative Cycles

We performed three rounds of formative design cycles, with slightly differing designs and participants. The second two rounds were conducted parallel to the method and tool development, with iterative updating of each.

In each study, participants were given a short text scenario describing a design problem needing requirements analysis in a particular domain (e.g., Parking app, Holiday shopping app), and a starting iStar model which was incomplete as per the description and domain, either on paper or in early versions of our tool. Participants were allowed to make changes or additions to the starting model, then were asked to apply several creativity techniques to the domain problem (Bright Sparks, Assumption Busting, Brainstorming, Pairwise Comparison, or Creativity Triggers), again either using the tool or on paper. Generated ideas were captured either on paper or digital post-it notes, placed on or near the model.

Creative ideas can be thought of as intentional elements, as per iStar, something desired by one or more actors, but as yes without a defined type (e.g., goal, task) or even multiplicity. An idea can be quite vague and high-level, and can thus be broken down into more than one iStar intention. In some cases, ideas are big enough to involve the introduction of new actors. For example, an idea from Fig. 1 is that the device, capturing biometrics, should be linked to a smart phone. This can map to one or more intentional elements, e.g., a task "capture biometrics" and a goal "link to smart phone", with a smart phone actor depending on the app for a dependency resource, "biometrics".

After each activity, participants were asked to cluster their ideas near related elements (if possible) and then to incorporate (some of) their ideas into the iStar model, i.e., create new iStar elements, actors and links which capture the idea, and add these new constructs to the existing model, replacing the idea. Participants summarized their experience via a questionnaire. The first author facilitated the studies, taking notes and video. Focusing on the initial research question (IQs), she paid particular attention to the way participants worked with ideas and the model, looking for actions or combinations that did or did not work well, in order to inform method and tool design. See Fig. 1 for an example photo from the first round of the study showing a high-level view of the paper model, clustered ideas, and hand-drawn model additions.

3.3. Observations

We summarize our findings, combining observations of both our exploratory and formative cycles. We organize our findings by our initial research questions (**IQ**s).

IQ1. *Are goal modeling and creativity techniques complementary? If so, how?* There was a general agreement amongst participants via their responses to questionnaires that creativity and goal modeling work well together. In the exploratory studies we asked participants if they preferred to use modeling and creativity together, or only one or the other. 2/23 participants said they would perform only the creativity techniques, one participant said he/she would do

Figure 1: Photo from Cycle 3 Showing Post-its with Ideas Clustered on an iStar Model

neither, while the other 20 participants were in favor of a mix of techniques. One participant elaborated on their answer: "I think goal modeling provides a framework to think logically and completely. Creativity techniques helps to think out of the box. So the combination of these two will be very powerful." In cycle 3, we asked a similar question, only 1 out of 17 participants said they would not "Use both goal modeling and creativity techniques".

We noted that all groups in all studies were able to produce ideas, regardless of the ordering of activities. We also noticed that the combination of activities had a positive effect on flow. Participants often became "stuck" in the modeling process, particularly those without extensive iStar experience. The groups either ran out of things to add to their model, or the natural flow of modeling elements had stopped. In these cases, use of the creativity activities gave groups a "second wind", echoing the findings of others ([39]).

IQ2. *How can goal modeling and creativity techniques work together to enhance both goal modeling and creative output?* When observing the studies, the first author noted that performing a creative activity straight off, without the shared domain exploration provided by modeling, was often difficult. Many participants didn't know where to start, this appeared to be because were lacking a common understanding of the system, or that the system description provided (see exploratory study material at `https://tinyurl.com/cgmStudy` or [38]) was too broad or general. In the exit questionnaire for the initial exploratory studies, participants were asked if they would draw a goal model then apply some creativity techniques, or apply some creativity techniques then draw a goal model; they could choose both answers. 13/23 participants chose the former option, while 14/23 chose the latter. Participants were more likely to chose an option if that was the order they were given in their experiment protocol. They were also asked for their qualitative opinion on the ordering, with their answers coded as positive, negative, or neutral. 11 of the 15 participants who used goal modeling first gave a positive answer on this ordering, while 4/15 participants gave a more neutral answer. As an example positive answer "having drawn the goal model first gave the positive impact on creating new ideas. It made me to think how to improve the situation to achieve the goal and what else we need to do to lead the goal to be achieved". 4/8 of the participants who performed creative activities first gave a positive answer, while the other 4/8 gave neutral answers. 3/4 neutral answers related to the study time limit; participants did not have time to add the creative ideas to their model. Although more time could be given, incorporating divergent ideas into a single model would have been challenging, particularly for new modelers.

In the cycle 5 formative study, we asked participants "When during the modeling process should creativity techniques be applied? Before? Early? Mid? When complete?" 6/28 participants answered before, 10 answered early, 5 throughout, 7 mid-way through, 5 after completion, and 1 indicated he/she would like to choose. In later studies, we observed that groups who performed many creativity activities in sequence, generating many ideas, then had a challenging time clustering and linking these ideas to the model. The process was seen as overwhelming. On the other hand, groups who alternated between creativity and integration of their resulting ideas with the model had an easier time. It was more manageable to integrate 5-10 new ideas for each activity rather than 20 or more ideas for all. Generally, we observed that it was easier for groups to come up with ideas than to link those ideas to the model. The former was an unconstrained activity requiring little training, while the latter required them to constrain and ground their ideas, and have a working knowledge of iStar. Thus our advice to do these steps iteratively, to split up the more difficult task of linking and clustering ideas into smaller chunks.

Although results for IQ2 are mixed, they lead us to believe that creativity and goal modeling should be intertwined, starting with some modeling to support shared understanding, then moving into rounds of creativity techniques to generate ideas, with outputs iteratively incorporated into the model. We discuss this choice further in Sec. 6.

We also noted that when using some of the more specialized creativity activities, such as CRUISE or Pairwise Comparison, the participants would ignore the output of the activity and and just express ideas already in their head. It was clear that an initial round of simple brainstorming was needed to elicit all of the ideas which were obvious to the participants without further stimuli, echoing findings in previous workshops [4]. We saw that participants treated the post-its like first-class modeling objects, often linking them to other elements, sometimes using iStar links. Our tool was designed to support this way of working.

IQ3. *Do goal models help or constrain creativity?* We collected and tagged qualitative feedback from each participant via questionnaires. Feedback was tagged as positive, negative, or neutral. Participants gave mostly positive answers when asked if the goal model helped them come up with ideas and was not constraining. In cycle 3, we asked "Did the goal model help you to come up with ideas? Or did it constrain the ideas generated? Why?" 8/16 answers were tagged as positive, 7 as neutral, with one unreadable. An example positive answer was "the starter goals were good "seeds" for producing new ideas", while an example neutral answer was "It helped keep on track with idea generation but the initial seeding may have resulted in constraints". In cycle 4 and 5 we asked "Do you think the contents of the goal model are more creative after applying creativity techniques? Would the resulting requirements and system be more innovative?" 22 out of the 28 participants who completed the questionnaire in cycle 4 said yes, while 7/11 participants in cycle 5 said yes.

We noted that working through creativity activities after goal modeling, users would occasionally refer back to the models for reference, but generally ignored the models and worked through the activities independently. In this way, by flipping back and forth between modeling and creativity, users did not appear to be constrained by the model.

IQ4. *Can creative ideas be related back to the goal model? How?* Participants were able to cluster most ideas to related elements in the model, and often ideas could be grouped together (see Fig. 1 for an example, the other figures can be found online and are similar). Those few ideas that could not be clustered or linked were in the domain, but not related to the subset of the domain captured in the goal model. This is not necessarily undesirable, but means either the model should be expanded in the direction of the unclustered/unlinked idea, or that the idea should be discarded.

In the exploratory study, e included an investigation of convergent creativity. Participants were often able to express their creative ideas in terms of the model, e.g., adding new actors or softgoals, but did not have time to add these constructs to the model. The formative studies, groups were able to model some of their ideas in iStar, if enough time remained, but this was a much slower and more "painful" process compared to the initial divergent creativity activities and idea discovery. In cycle 3 we asked "Was it easy or hard to capture creative ideas in the goal model? Why?" 6/16 results were positive, 7 neural, and 3 negative. Unsurprisingly, participants' ability to model their ideas depended greatly on their level of iStar expertise – this task was particularly hard for those who had only used iStar in a course.

IQ5. *Do certain creativity activities perform better or worse than others when used with goal models?* All groups could successfully produce ideas with all activities applied. We did not notice any obvious differences in the effectiveness of particular creativity techniques. Some groups had particular preferences, but these preferences varied between groups. As such, we did not design our summative cycle to examine the differences between each activity, but the use of the activities as a whole.

We were also able to make some observations concerning group size; specifically, in groups with more than three members, at least one member was often mostly silent and left out of the process, leading us to believe that with the support of current technology, i.e., a single monitor, optimum group sizes are 2-3. Group dynamics is a rich research topic (e.g., [40]); further exploration is out of the scope of this paper.

4. Creative Leaf: Tool & Method

Using insights gained via exploratory and formative design cycles, we created a tool and associated method to guide users through a creative goal modeling process. A brief description of the Creative Leaf tool has appeared in [21], we expand on this description here.

4.1. Method

We provide a suggested method for creative RE, noting in our formative studies that users needed such guidance through the creative process. Our method is summarized in Fig. 2, including a mapping to selected creativity theories. We aim for a balance between flexibility and guidance, thus we intend for steps to be iterative, based on the judgment of the participants. The method starts with the creation or expansion of a goal model, then moves to exploratory creativity activities, starting with brainstorming. We recommend clustering new ideas near related iStar elements, connecting with iStar links after each activity. Experience shows this should be done after each creativity activity, instead of at the end of all activities, else the users are overwhelmed with too many ideas to link and cluster at once. The built-in evaluation feature can be used to evaluate the ideas, using the output to prioritize and select ideas. The best ideas can be incorporated into the model using iStar constructs. Our most recent validation cycle focuses on evaluating Step 2 and its sub-steps, with some initial data on the outcomes of Step 3 and 4. We discuss alternative methods in Sec. 6.

4.2. Creative Leaf Tool

Creative Leaf is an online tool, developed primarily in JavaScript, with features tested in Chrome[2]. See Fig. 3 showing the Creative Leaf interface. The tool has two primary functions: iStar modeling, facilitated via a palette (left) and canvas (middle), and the application of creativity techniques, facilitated via

[2] Readers are encouraged to try out the tool: `http://creativeleaf.city.ac.uk/` or `http://creativeleaf.portal.chalmers.se/` (Best used in Chrome)

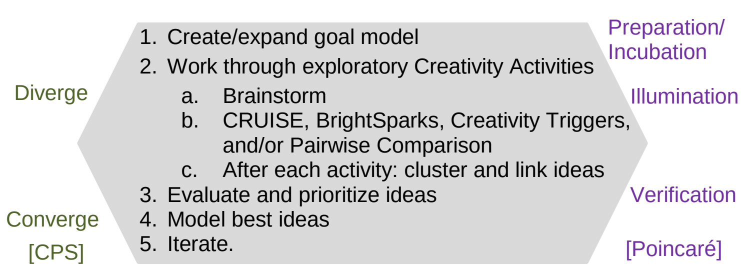


Figure 2: Creative Leaf Method, Mapped to Creativity Theories

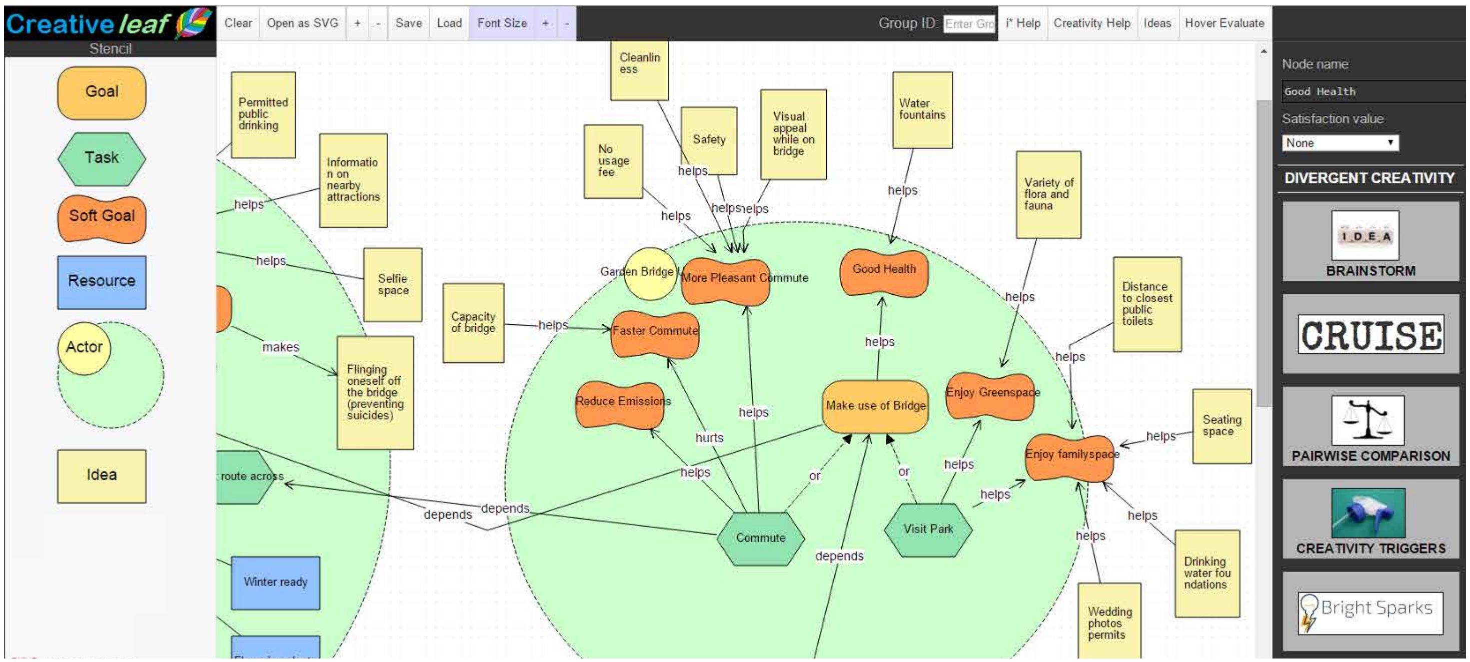


Figure 3: Creative Leaf Tool Screenshot

the creativity panel (right). The model in Fig. 3 shows a sample output of our summative studies (Sec. 5), concerning the London Garden Bridge.

The modeling component is based on the Leaf tool developed at the University of Toronto [41]. Leaf makes use of the JointJS modeling library[3], including the Rappid diagramming framework. Creative Leaf, Leaf, and JointJS are open source, while Rappid requires a license, but provides free licences for academic purposes. The modeling tool allows you to draw iStar intentions, actors, and the expected set of links as per [22]. Added to the list of drawable iStar intentions are ideas (yellow boxes), the output of divergent creativity techniques, linkable to any other element via iStar links.

Divergent Creativity. The creativity palette includes five divergent creativity activities. When the user clicks on an activity, it opens as a window within the Creative Leaf tool. Although the window can be moved, re-sized, or minimized, it generally blocks most of the goal model content. Thus the creativity activities are mainly performed without seeing or accessing the goal model. Sometimes a warning is given that the user must select an intention or actor before opening the activity. All activities (except Brainstorming) take as input some part of the model and provide some stimuli. All techniques allow the user to enter ideas via a text box. When the user selects "Add idea to Model Canvas and Exit" or "Add idea to Model Canvas and Continue", ideas are automatically added to the canvas as idea elements. These ideas can be linked to other iStar elements with standard links. Thus, their addition to iStar produces a simple extension: a new idea element.

The user is intended to start with Brainstorming, in order to urge the early discovery of "obvious" ideas. This opens a simple window (not shown) with a space to write ideas.

The second activity in the palette is CRUISE creative search, shown in Fig. 4[4], making use of a pre-existing creativity web service, embedded into Creative Leaf via an activity window [36]. Note that the order of CRUISE and the next three divergent activities in the palette is not significant, they can be used in any order. The CRUISE engine searches the web for results which are tangentially related to a search string, producing results which are more indirect than, for example, Google Image search. In our embedded version, the user picks an iStar element, in the Figure this is "Make use of Bridge", and clicks the CRUISE button on the creativity panel. The text of the element name is fed into CRUISE as a search string. A pop-up appears showing a click-able word and image cloud relating to the element. The user can hover over images to increase their size. The output is intended to stimulate the generation of ideas, which can be written in the bottom of the pop-up window. The CRUISE search results are received from an external call to the CRUISE web service, integrated into Creative Leaf.

Fig. 5 shows the next activity in the palette, our implementation of Pairwise Comparison. The user can either click on the button to pick a random pair,

[3]http://www.jointjs.com/

[4]More readable screenshots can be found in [38]

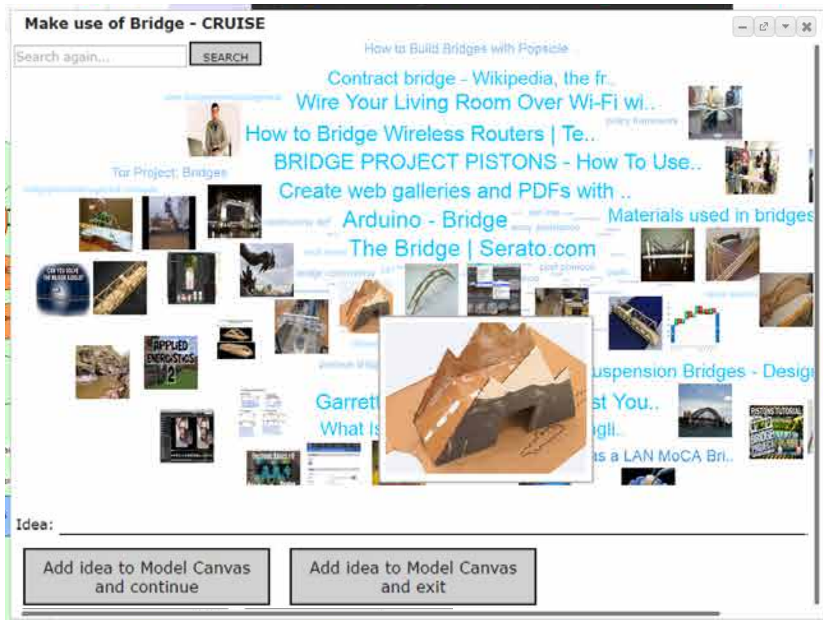


Figure 4: Creative Leaf CRUISE Activity

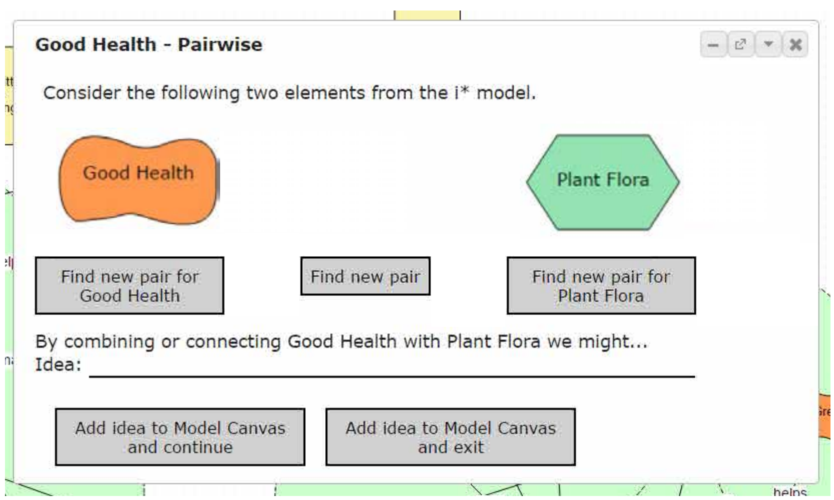


Figure 5: Creative Leaf Pairwise Activity

or can select a single element, in which case Pairwise picks another element to form a pair. The text prompts users using the names of each element, e.g., "By combining or connecting Good Health with Plant Flora we might..." prompting the discovery of ideas based on the pair combinations. The user can iterate through pairs, picking an entirely new pair, or a new element on the left or right side. In our exploratory studies, we noted that combinations of two softgoals seemed too abstract for users, thus each pair contains at least one task, goal, resource or actor. We also avoid showing pairs of elements which are directly linked, showing elements without obvious associations.

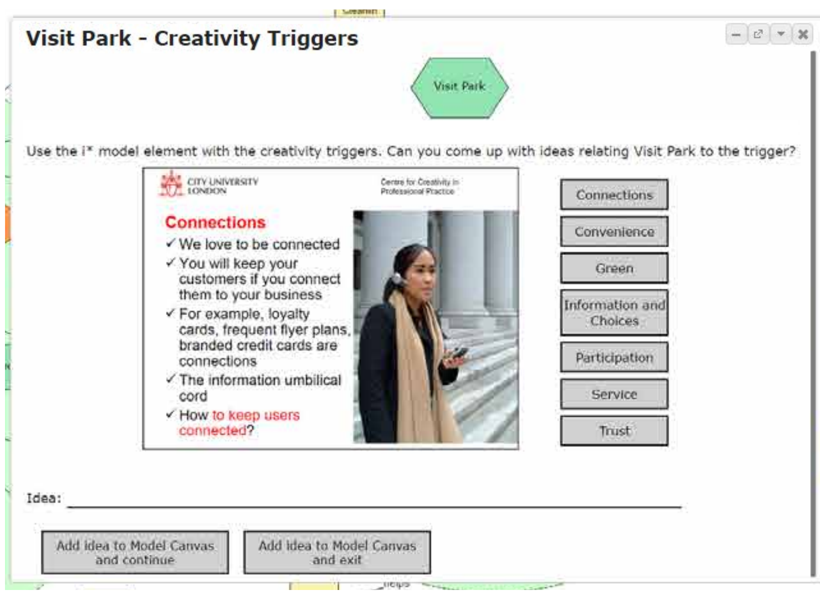


Figure 6: Creative Leaf Triggers Activity

The fourth activity is our implementation of Creativity Triggers, shown in Fig. 6. Users can look through all triggers on their own, or select an element from the canvas to associate with the triggers. In the Figure, the user can think of the association of "Visit Park" with Connections, Convenience, Green, Information and Choices, Participation, Service or Trust. Each trigger has explanatory text, an example, and images (see the Connections example in Fig. 6).

Finally, Fig. 7 shows Bright Sparks, another pre-existing web service embedded into Creative Leaf via an activity window [35]. Users click on an actor and are shown a famous persona, complete with description and set of "Sparks" or prompts. The user can iterate through the Personas and Sparks. The text at the top links the actor with the persona, for example: "Imagine Mario is playing the role of the Garden Bridge User..."

Selecting & Converging. We have added initial features to Creative Leaf to facilitate convergence, the selection of ideas, encouraging users to incorporate their best ideas in the model. These features have undergone less design and evaluation, compared to features for divergent creativity, and are described

Figure 7: BrightSparks in Creative Leaf

briefly here. Future studies will further refine their function and evaluate their effectiveness.

We've added a simple form of qualitative propagative evaluation to the tool, "Hover Evaluate", where elements that users hover over are assumed to be satisfied, and the qualitative results are propagated up the model, as per the typical rules [42]. This feature is aimed to allow users to quickly explore their ideas without having get into the specifics of qualitative analysis.

The tool contains activities to help with idea selection and modeling. The Converge activity provides instructions on the use of the Hover Evaluate feature, encouraging users to explore the affects of ideas, adding additional help or hurt links if necessary. Users are instructed to consider the hover evaluation results, then to mark ideas as *rejected*, *maybe*, or *must have*, using available halo buttons, appearing when hovering over an idea. Rejected ideas disappear from the canvas, but are available to be viewed via the Ideas pop-up. This pop-up shows all ideas created, including their status (*rejected*, *maybe*, *must-have*, *modeled*). It allows users to add any idea removed from the canvas back to the canvas. The final Modeling activity instructs users to model the *must have* ideas using iStar constructs. When an idea is modeled, it is marked as *modeled*, and removed from the canvas.

Embedded Method & Tracking. We guide users through our suggested method via a "Creativity Help" button, which displays our suggested method, showing green check marks when the particular step has been completed in the current browser session. We have also implemented a series of unobtrusive prompts, based on the activities performed, guiding users to the likely next step, which appear in the top corner of the screen, and are easily dismissed.

Finally, we've added code to track user activities (modeling adds/moves/deletes, creativity activities, ideas generated, unobtrusive prompts, etc.) facilitating data collection for our summative studies (Sec. 5) and setting the tool up for future data analysis after public release.

5. Summative Validation Cycle

We describe the validation results of our most recent design cycle, focusing on a summative evaluation of Creative Leaf's support for divergence creativity (steps 1 to 2 of our suggested method in Fig. 2). The full study design including instructions, questionnaires and raw results can be found online under "Summative Validation Studies" `https://tinyurl.com/cgmStudy` or [38], Cycle 6.

Design. The design of our first validation study was similar to that of the formative studies in Sec 3.2. The main differences included: only two participants per group, guidance via study instructions with no explicit facilitation, recording videos describing the model before and after applying creativity techniques, and recruiting urban design experts to evaluate the novelty & utility of the output by watching the videos. We recruited six groups of two participants. Two participants were Graduate Students in a Creativity-related Master's at City, University of London (2), the other ten participants were graduate students and researchers at the University of Trento (4) or Toronto (6) with an RE and technical background. 5/12 of the participants had participated in one of the rounds of exploratory or formative studies. We performed one pilot study to evaluate the clarity of the study design.

The study focused on designs for the Garden Bridge in London, a plan to build a garden on a pedestrian bridge over the Thames, creating innovative urban green space[5]. Although ideas and solutions produced this space are not necessarily technical, the problem space could involve software and technology (apps, social media, sensors, etc.). While our previous domains of study were more software-intensive, we select this domain as it is easier to understand for our stakeholders (two out of twelve of which are non-technical), and to begin to understand whether the results of our method are limited to systems with an emphasis on software, or can be applied more broadly. The resulting goal model and ideas could be transformed to system requirements, as in any software-related domain.

Participants were given study instructions, including access to Creative Leaf and a starting, incomplete iStar model. The study was divided into four parts; we recommended 30-40 minutes for each part. In the first part, participants were asked to adopt, expand and change the starting iStar model, to "make it their own". They were then asked to create a short (< 5 minutes) video (*Vid1*) describing the model and their solution, aimed for an audience who did not know iStar (see study instructions online for more detail). In the second part,

[5] `https://en.wikipedia.org/wiki/Garden_Bridge`

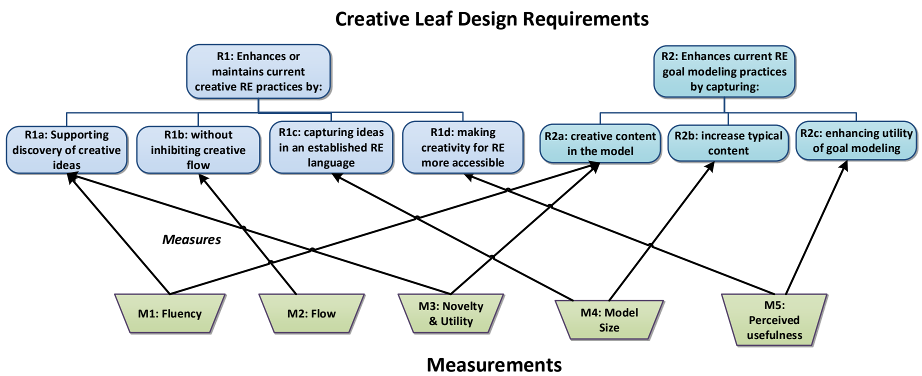


Figure 8: Creative Leaf Design Requirements Mapped to Summative Study Measures

participants were then asked to work through the divergent creativity techniques in the model, linking and clustering ideas in the model after each activity.

In the third part, participants were asked to use the hover evaluate feature to explore their ideas, coming up with a final prioritization for their ideas (reject, maybe, must have). The participants were asked to make two final videos, one describing their final model and best ideas (*Vid2*), and the final one their reflections on the process and tool (*VidF*). Participants could perform the study on their own time, without facilitation, providing the study designers saved models and descriptive videos. Creative Leaf kept a log of their activities. The study took 1-2 hours to complete.

5.1. Measurements

In order to determine if our artifact (method & tool) meets the requirements outlined in the introduction (**Rs**), we derive several measurements (**M**). Fig. 8 summarizes the mapping from requirements (**R**) to measures (**M**).

M1: Fluency. We measure fluency using the simple but widespread measure of idea fluency (count of ideas) as per Guilford [43].

M2: Flow. To evaluate flow, we examine the time-stamped logs of activities provided by creative leaf, classifying the activities into different categories. When looking for flow, we are generally looking for bursts of uninterrupted activities. Our evaluation of flow is intended to be descriptive, not statistical.

M3: Novelty & Utility. We measure novelty and utility, using expert judgment, recruiting a total of five experts in urban design. We provided the experts *Vid1*, describing the model before the creativity activities, and *Vid2*, describing the final model after creativity activities, from each group (12 videos in total). Our experts judged the novelty and utility of the videos in separate 5-point Likert scales.

M4: Model Size. We measure model size by looking at the increase in model size after each of the four parts of the study. We measure size increase looking at both new elements and links, including idea elements.

M5: Perceived Usefulness. We examine the qualitative outputs of the participant reflection videos.

Although we use such measures to address our research questions, it is important to note that these measures do not come with set targets. There is no agreement on how many ideas are sufficient in a creative process, or on appropriate sizes of iStar models. As there is no baseline targets, measurements are compared relative to each other at various stages in the process. We address this point and other points when considering threats to validity in Sec. 6.1.

5.2. Results

M1: Fluency. We summarize the results of the six groups in the first two columns of Table 2, highlighting the ideas the groups chose to highlight in *VidF*. Note that not all ideas by all groups were prioritized. We show the total count of ideas for each group in the Num Ideas column of Table 2. The groups came up with a range of 4 to 37 ideas during their session, with an average and median of 20 ideas. We can see a fairly wide range in number of ideas per group, although all groups came up with ideas, and only one group had fewer than ten ideas. A deeper analysis of the differences between groups can be gained by analyzing flow.

M2: Flow. Fig. 9 shows the time-plotted activities of each group, facilitated by the tracking added into Creative Leaf. To reduce complexity, we show only the first half of the study, before the groups began convergent activities. The plotted time duration for each group's activities is 1 hour 40 minutes, in order to facilitate comparison on the same scale. The small (blue) x's indicate modeling activities, in this case the creation of an iStar element or link. The small (orange) circles on the same horizontal line show the creation of an idea. The larger shapes on the line above show opening and closing particular creativity activities. Note that it was possible to minimize and not close an activity.

We can interpret Group 1 (G1)'s activities at the top of Fig. 9: the group spends about 15 minutes of intense modeling, then has a period of relative inactivity, which includes the creation of the first video *Vid1* describing the model before creativity, then starts the Brainstorm activity, coming up with a burst of ideas, then closing the activity. The group has another burst of modeling activity, then opens CRUISE, comes up with several more ideas, a small amount of modeling, CRUISE again with a few more ideas, another burst

Group	**Best Ideas after Creativity**	**Num Ideas**	**Must-have**	**Maybe**	**Reject**
G1	Camping on bridge, lend umbrellas, host events with prizes	37	13	15	9
G2	Bridge trolls, separate selfie space, social media infographics	26	11	10	2
G3	Aquarium, add movies to be played on bridge, music DJ	11	7	2	2
G4	Have places for bike rentals, lectures to attract audiences	4	2	1	1
G5	Fancy bridge with two floors, Mario path and figure to encourage walking, food	19	4	14	1
G6	Safe environment, Sporting events, Showcase London as tourists and locals friendly	21	12	8	1

Table 2: Summative Study Idea Summary

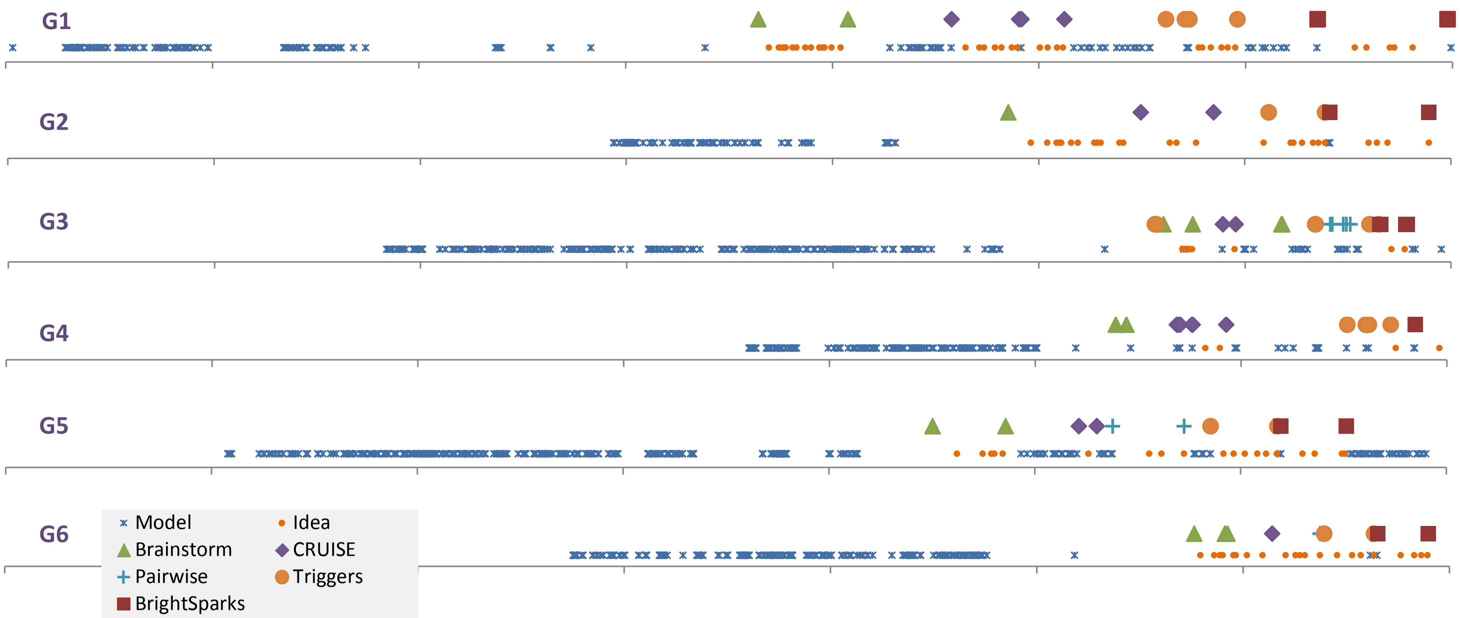


Figure 9: Summative Study Group Tracking (each time line 1 hour 40 minutes duration)

of modeling, a few tries of the creativity triggers, with a burst of ideas in the last try, more modeling, then a longer period of Bright Sparks producing a few ideas. The other groups can be understood similarly: G2 has a fairly short but intense period of modeling, then tries Brainstorming (leaving the window open), CRUISE, Triggers and Bright Sparks, gaining ideas, but doing minimal modeling. G3 has a very long and intense period of modeling, then a rather short period of trying all the activities, producing a few ideas with intermittent modeling. G4 has an intense period of modeling, then tries most activities, but generates few ideas. G5 has a long an intense period of modeling broken at the end, then tries all activities, generating ideas with periods modeling in between. G6 has a modeling period which starts and stops then becomes intense; they break then make quick tries of activities with ideas generated but minimal modeling.

We can see some evidence of idea flow, particularly in G1, G2, G6, and to a lesser extent G5 – periods within the creativity activities where many ideas come quickly. G3 had an intense period of idea-generating in brainstorming, then did not manage to generate many ideas in the other activities. G4 did not generate many ideas overall. We report more detail about group experiences when discussing **M5**.

Fig. 9 also shows evidence of modeling flow, periods with bursts of clustered activity with the model. Notably, we can see visual evidence which supports the idea that groups "get stuck" or "run out of steam" with modeling before moving to creativity [39]. The gap between the modeling and creativity for many groups can be explained by the creation of the first video, but even before the gap we can see signs of slowed modeling activity, particularly with G1, G2, G3, and G5, where the modeling activities start to slow down or break apart before stopping. In some cases the groups may have deliberately stopped their modeling flow due to time constraints, as was reported by G2. However, even in this case it appears that the modeling activity was slowing down even before the grouped forced themselves to stop.

M3: Novelty & Utility. We measure novelty & utility using expert judgment, recruiting five experts in urban design from personal contacts and via mailing lists. We provided the experts *Vid1*, describing the model before the creativity activities, and *Vid2*, describing the final model after creativity activities, from each group (12 videos in total). Our experts judged the novelty and utility of the videos in separate 5-point Likert scales. The first two experts were given the 12 videos in a random order and asked to write the number corresponding to the score (thus some decimal values results). Upon reflection, we decided the experts would be able to match together videos from the same group. Thus, for the last three experts, video order was also randomized, but with the before (*Vid1*) and after (*Vid2*) video for each group shown consecutively. In this case users had to pick one number on the 5-point scale instead of entering a number, thus all our responses are whole numbers.

Vid1							***Vid2***						
		Expert							Expert				
Group	**Type**	**1**	**2**	**3**	**4**	**5**	**Group**	**Type**	**1**	**2**	**3**	**4**	**5**
1	Nov	3	3	3	2	3	1	Nov	4	5	3	2	5
1	Utl	4	3	4	2	3	1	Utl	4	5	3	2	5
2	Nov	4	3	5	3	2	2	Nov	4	4.5	4	5	2
2	Utl	3	3	4	3	2	2	Utl	4	4	4	5	2
3	Nov	3	2	3	2	4	3	Nov	3	4	4	3	4
3	Utl	3	3	3	2	4	3	Utl	3	4.5	3	4	5
4	Nov	2	1	2	2	2	4	Nov	2	3	3	2	2
4	Utl	blank	2	3	2	2	4	Utl	2	3.5	4	2	2
5	Nov	3	3.5	3	3	2	5	Nov	2	4	4	4	2
5	Utl	4	4	3	3	3	5	Utl	2	4	4	4	4
6	Nov	4	3	3	4	3	6	Nov	2	2	3	4	4
6	Utl	3	2	3	4	3	6	Utl	3	3	3	5	4
Avg	Nov	3.2	2.6	3.2	2.7	2.7	Avg	Nov	2.8	3.8	3.5	3.3	3.3
Mode	Nov	3	3	3	2	2	Mode	Nov	2	4	3	3	3
Med	Nov	3	3	3	2.5	2.5	Med	Nov	2.5	4	3.5	3.5	3.5
Range	Nov	2-4	1-3.5	2-5	2-4	2-4	Range	Nov	2-4	2-5	3-4	2-5	2-5
Avg	Utl	3.4	2.8	3.3	2.7	2.7	Avg	Utl	3	4	3.5	3.7	3.7
Mode	Utl	3	3	3	2	2	Mode	Utl	4	4	3	2	5
Med	Utl	3	3	3	2.5	2.5	Med	Utl	3	4	3.5	4	4
Range	Utl	3-3	2-4	3-4	2-4	2-4	Range	Utl	2-4	3-5	3-4	2-5	2-5

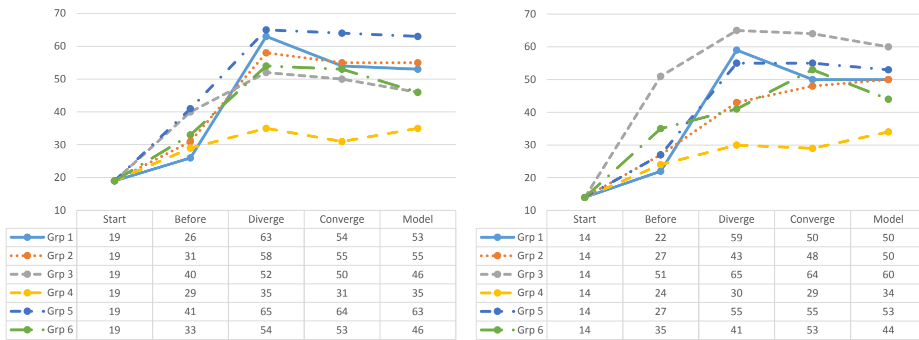
Table 3: Expert Novelty & Utility Scores for Group Videos (Nov (Novelty), Utl (Utility))

Expert scores are shown in Table 3. Average novelty scores for *Vid1* ranged from 2.6 to 3.2, and from 2.8 to 3.5 for *Vid2*[6]. We can see average novelty increased for 4/5 experts from *Vid1* to *Vid2*, with increases from 0.3 to 1.2, while Expert 1's novelty score decreased by 0.4. The mode and median increase for 7/10 of the values collected (2 per expert). Average utility scores for *Vid1* ranged from 2.7 to 3.4, and from 3 to 4 for *Vid2*. We can see average utility increased for 4/5 experts from *Vid1* to *Vid2*, with increases from 0.2 to 1.2, while Expert 1's utility score decreased by 0.4. The mode and median utility scores increase for 7/10 of the values collected. Overall we see slight increases in both novelty and utility from *Vid1* to *Vid2*, particularly for 4/5 experts.

In addition to these overall positive results, we note that the groups themselves evaluated most of their ideas as sufficiently novel and/or useful, choosing to reject very few ideas as shown in the last column of Table 2.

M4: Model Size After starting with the same model (Start), each group created several versions of their model. Here we report statistics on the size of the model after expansion and before conducting creativity techniques (Before), corresponding to the models described in *Vid1*; the size of the model after creativity techniques were applied (Diverge); the size of the model after

[6]There are issues with taking the average of ordinal data [44]. As our data is descriptive and not statistical we make use of averages as a heuristic summary. We also calculate the median, mode, and range.



	Start	Before	Diverge	Converge	Model
Grp 1	19	26	63	54	53
Grp 2	19	31	58	55	55
Grp 3	19	40	52	50	46
Grp 4	19	29	35	31	35
Grp 5	19	41	65	64	63
Grp 6	19	33	54	53	46

(a) Element Count Across Six Groups

	Start	Before	Diverge	Converge	Model
Grp 1	14	22	59	50	50
Grp 2	14	27	43	48	50
Grp 3	14	51	65	64	60
Grp 4	14	24	30	29	34
Grp 5	14	27	55	55	53
Grp 6	14	35	41	53	44

(b) Link Count Across Six Groups

Figure 10: Element and Link Data across Six Groups at Different Part of the Study

prioritization and convergence over ideas (Converge); and the size of the model after some ideas were modeled (Model), corresponding to *Vid2*. Fig. 10 presents the size of the models for each group at each part of the study, including iStar elements (ideas, actors, goals, tasks, softgoals, and resources[7]), ideas, and iStar links. Part of a sample resulting model is shown in Fig. 3.

Generally, we would expect each group to expand the starting model (Start to Before), then for the model size to increase after divergent creativity (Before to Diverge). Looking at Fig. 10 we can see this is the case, although the degree of expansion varies per group. After divergence, we would expect the size of the model to decrease slightly (Diverge to Converge), as some ideas and associated links are rejected (recall that *maybe* and *must-have* ideas remain in the model). We can see such a decrease in most groups, with the exception of Group 6. During the modeling (Converge to Model) it was difficult to predict how the size of the model would change, on one hand ideas and associated links are removed from the canvas, but on the other hand new elements and links are added. In this case, we see a mix of small increases and decreases in size.

Overall, for all groups, we can see that creativity activities increase the size of the iStar model in terms of elements and links (Diverge, Converge, and Model counts are all larger than Before). In most cases, the increase in size is significant (almost double), with the exception of Group 4.

M5: perceived usefulness. Analyzing *VidF*, the groups reported the tool was useful in generating ideas, although some groups complained about specific tool design aspects like drawing iStar links or small screen space. In their *VidF* summary video, G1 compared the model after creativity activities to before "P(articipant)1: I think we got quite different areas covered, we didn't just think in one direction, different words. P2: Yeah that's true, it gave a bit more breadth to the thinking, which could be considered more creative? P1: We got a lot of good ideas, actually, we kept almost all of them. P2: Yeah, we

[7]Actors and ideas are not usually considered iStar elements, but we include these concepts in the element count for simplicity of data reporting.

did actually, and maybe they're ideas we wouldn't have thought to put into a stringent sort of model, without those triggers and activities." A G2 participant summarized the experience: "Creativity techniques helped us to come up with and understand our model better. And to come up with things that we didn't think of before". G4 emphasized the importance of group creativity: they came up with good ideas based on their discussions, together with application of the creativity method.

G3 commented on the synergies between iStar and creativity: "We think that iStar and the creativity techniques that were suggested in the study, especially the CRUISE one, are really complementary to each other. For example, ... after doing iStar, when we started the creativity techniques we came up with some sort of new tasks and softgoals in the model." Although their impression was positive, G3 particularly complained about the usability of the modeling part of the tool, which may account for their relatively low number of ideas.

G4 reported they were not able to separate modeling and brainstorming; they brainstormed intuitively when modeling, thus they skipped that technique (they opened it but entered no ideas). However, Fig. 9 shows their ideas were generated during or after using creativity techniques. Although not explicitly described in our method, it is fine to add ideas when modeling, separate from the use of creativity techniques. The problem is if users think this is a substitute for using the techniques, not taking advantage of their diverse input to the creative thinking process.

In terms of the perceived usefulness of individual activities, there was a bug (now fixed) in Pairwise comparison which prevented several groups from using it (G1, G2, G4), but G6, one of the groups who used this technique successfully, said it was helpful. G2 did not find Bright Sparks as useful as they were not familiar with the persona that came up, but thought it could be more useful if they kept trying. G5 really liked Bright Sparks, because they found the personas fun, but had less luck with CRUISE as the element they searched for did not give inspiring results, while G3 reported that positive feedback for CRUISE. These results echo our experiences in the exploratory and formative studies: we see no obvious indicators that one technique is generally more effective, different groups have differing experiences. This supports our design: giving users a variety of creativity techniques to choose from.

Our results give us insights concerning our methodology. Recall that we suggested users start with modeling, then switch between creativity activities and periods of clustering and linking ideas. G1, G3, G4, and G5 appeared to have followed the method, while G2 and G6 did not appear to integrate their ideas into the model during the period of exploratory creativity. G6 reported that they deliberately chose not to cluster or link activities to the model, as they felt it would restrain their thought space. Although this is a valid point, when the groups are actually coming up with the ideas in the activities the model is hidden. Encouraging the groups to go through all activities without thinking about the model, as G2 and G6 have done, would certainly be optimal for creative flow. However, we've seen in our exploratory and formative studies that the subsequent task of sorting, linking and or selecting all the resulting ideas at once is daunting. Further studies are needed to assess possible orderings.

5.3. Analysis

Here we return to the results of our five measures, using them to assess satisfaction of the requirements for our tool and method.

R1: Enhances or maintains current creative RE practices. We look at whether Creative Leaf *(R1a:) Supports discovery of creative ideas*, by examining fluency (M1) and novelty & utility (M3). In terms of fluency, all groups could come up with ideas, an average of 20 (see Table 2). Although the number of ideas differed greatly between groups, we can generally see signs of creative output. The overall assessment of novelty and utility increased from examining the videos describing the model before to after creativity activities. With this evidence, along with the use of established creativity techniques, we see some early evidence to support the claim that Creative Leaf supports the discovery of creative ideas.

We can examine whether or not Creative Leaf supports such idea generation *(R1b:) without inhibiting creative flow* by examining our flow results in Fig. 9. Here we see some evidence of bursts of ideas, and in a few cases groups were able to go back and forth between idea production and modeling. Recall that the tool was designed to hide or downplay the model contents during divergent idea generation, participants had to minimize the activity to look back at the model. Overall, we see some evidence of flow, although, as with idea generation, this was not universal for all groups.

Our results show some evidence that users were able to *(R1c:) capture ideas in a simple extension to a well-known RE language*. Results show that most groups had no trouble adding ideas as idea elements, linked to more standard goal modeling concepts, capturing rationale. One can see this by the increase in model size, both in elements and links, from the Before to Diverge stages in Fig 10. A more thorough iStar integration, modeling ideas using typical iStar constructs (without ideas), was more difficult. This difficulty was partially due to iStar experience, and partly due to being pressed for time in the study. Even beyond these factors, taking into account observations in the exploratory and formative studies, it's clear that modeling creative ideas is more difficult than eliciting them, and further work is needed to better support this activity.

We argue that results for perceived usefulness (M5) are generally positive, helping to *(R1d:) make creativity for RE more accessible*, allowing the use of simple creativity techniques through a web-based tool without expert facilitation.

R2: Enhances current RE goal modeling practices. Results in Fig 10 clearly show that creativity techniques increase the size of the model overall. We argue that this increase in content would be difficult without the influx of ideas triggered by creativity techniques, as Fig. 9 indicates signs of reduced flow in modeling before creativity techniques were undertaken. The open question is how much of this new content is creative and how much is more typical? We argue that the new content is a mix of both. In line with the argument for *R1a*, we would argue that there is *(R2a:) creative content in the model as part of our simple extension*, while other parts of the new content are *(R2b:) more typical content*. Measuring specifically what is creative or more typical is difficult, but we argue that both type of content is useful, contributing both to the creativity and completeness of RE solutions.

Finally, our overall positive results for perceived usefulness (M5) indicate that the tool has *(R2c:) enhanced the utility of goal modeling* by allowing access to structured creativity, methods to increase model completeness, and a simple, web-based modeling tool.

6. Discussion and Future Work

As part of our exploratory, formative, and summative studies, we made many observations which fall outside of the scope of our initial requirements, leading to new research questions and several lines of future work.

Transformational & Combinatorial Creativity. In our exploratory studies, we applied the assumption busting technique, which could be potentially used to provoke transformational creativity, expanding and changing problem boundaries. Although this process prompted new, and often creative, ideas, the ideas were often in the current exploratory space, and did not usually result in transformational creativity. Overall, we believe that iStar models are at too low a level of granularity to easily support early, highly transformational creativity. This is in contrast to claims and experiences in [45]. Such fundamental scope shifts would often result in drastic changes to the model, or scrapping the model altogether. More effort is needed to understand how modeling can support more dramatic creative transformations, possibly storing sets of models, or better supporting model change.

Similarly, there is space to further explore combinatorial creativity. Although we include pairwise comparison in Creative Leaf, the natural extension would be to allow pairs selected by the activity to be merged. This raises interesting questions about finding pairs: should we work to find similar pairs, dissimilar pairs, or let the users find pairs via chance? In initial versions of pairwise comparison, we used the semantic similarity score used in the evaluation in order to try to find pairs that were not too similar or dissimilar (bearing similarities to recent work by Bhowmik et al. [46]). After evaluation, we decided there was not enough text in individual elements for the scores to be relevant, and abandoned this line of design. Further investigation is needed to discover how iStar can support combinatorial creativity.

Method Ordering. Should creativity techniques be performed before or after iStar modeling? Creative Leaf allows either approach, but our method advises users to start with modeling, as we are concerned that initially elicited ideas, without a shared form of grounding in a model, would be too diverse and conflict. We fear that it would be too difficult to convert such early ideas to a single iStar model, as such ideas would cover a wide ranges of potentially conflicting possibilities. This relates to the challenges of modeling transformational creativity. Future work with more advanced tooling is needed, including support for many possible models representing different creative alternatives.

Clustering. Users can effectively cluster their ideas near related elements in the model manually, but computational support for this process could be desirable. The tool could either cluster ideas near the iStar element which was used as in input for the creativity activity, or to use semantic measures to find the iStar elements which are similar to the idea. Studies are needed to evaluate these possible solutions.

Sketching. It would be useful to link our work to tools supporting electronic sketching. In some cases, users wanted to sketch ideas, supporting pictures in addition to text would offer an extra dimension of expression.

Modeling Creative Ideas. Participants were generally able to transform their ideas into iStar constructs; however participants found this activity difficult. The expert participants were able to do so at a faster rate than the novices, producing many more elements. Even for experts, this process was laborious and time-consuming. Future work should look at reoccurring patterns when turning ideas into iStar elements. These patterns could be collected and used within the tool, along with parsing of the idea text, to suggest starting model fragments for each idea, easing the modeling process. Semantic similarity scores could suggest connections to and from these model chunks to pieces of the existing model. More work is needed in this area, particularly as it makes iStar more accessible to new or inexperienced users.

Scalability, Convergence & Prioritization. We observed that participants were typically coming up with far more ideas than could be practically modeled, in terms of time, effort, and model complexity. We have addressed this by incorporating evaluation, selection and prioritization into Creative Leaf, but more work is needed to evaluate and refine our early design of these activities. For example, we have seen that although users can link their ideas to the model, usually they use a help link. They rarely model negative consequences of their ideas, all ideas are good. Thus far participants were able to fairly easily prioritize their ideas into must-have, nice-to-have, and reject, but were not easily able to use the model to justify their prioritization, the knowledge informing these decisions was mainly kept tacit. Future work must try to better support rationalization using the model.

Generally, although iStar models are expressive, it is well established that they suffer from issues in scalability and complexity. We acknowledge these issues, and look to recent work on modularity [47, 48], as well as new advancements in tooling to help mitigate these issues.

Systems vs. Software. While some RE books focus specifically on software requirements (e.g., [49, 50]), others consider RE as applying more broadly to both software and systems (e.g., [51, 17, 52]). Berenbach et al. frame RE as a "domain-neutral discipline", applicable to software, hardware, and electromechanical systems [51], while Robertson and Robertson focus on RE for products or projects [17], and Kotonya and Sommerville focus on (computer-based) systems [52]. In the literature and the authors' past experience, goal modeling and creativity as individual methods have applied well to both software-intensive and more general systems (see Sec. 1). In this work exploring the combination of techniques, we have focused initially on software- and computer-based systems in our exploratory and formative studies, but then used a more general system in the final summative study. Here we do not see an obvious difference in the results due to the level of software involvement. We believe this is because both goal modeling and creativity typically work at a high-level of abstraction, describing solutions in a technology-neutral way. For example, one of the more detailed resulting ideas "social media infographics" is still quite general. It implies the use of some social media, but not which platform, or the choice of what data to show. Future studies using goal modeling and creativity can confirm or deny our findings, measuring effectiveness for requirements problems leading to different types of solutions.

6.1. Threats to Validity

We consider threats to the validity of our initial validation study. Our study reflects an intermediate validation of a work in progress, thus we have not aimed for statistical significance. Still, we use threat categories in [53] to structure threats.

Internal validity. It is impossible to completely separate evaluation of iStar modeling difficulties from evaluation of Creative Leaf. We tried to mitigate this factor by finding participants who had some exposure to goal modeling. The actual amount of experience with goal modeling differed widely, from learning it in a course and applying it to a single assignment, to forming an important part of their thesis work. In this way, we can claim that the tool is usable even for those with less goal modeling experience. Future studies should look at whether the tool is still usable and effective for those who are not familiar with goal modeling, or even conceptual modeling in general.

Conversely, we did not focus on finding students familiar with structured creativity. Only the City Students (G1) learned about creativity in a structured environment. Some of the other students would have had exposure through previous tool use and research talks, and others no exposure at all. Although a creative background may have an influence on the result, we were open to different levels of expertise in this area, in the name of finding enough participants.

As mentioned, five participants participated in both the formative and summative studies. This was necessary, as it was difficult to find participants who knew goal modeling and were willing to donate their time. This will have a learning effect on results: the tool should be easier to use a second time. However, we believe that the learning affect would have more influence on their technical capacity to use the tool than on their ability to generate creative ideas. Note that both members of the "best" and "worst" performing teams in terms of number of ideas generated were new to the tool and study (G1 and G5), all other teams had at least one member who had participated a previous round of study. The primary difference between G1 and G5 members was the level of creativity training, outside the tool. The purpose of our summative study was to show that Creative Leaf has promise to satisfy its requirements (**R1-2**) in general, for a variety of users, and not necessarily only for new users.

As most of the participants are known to the researchers, this may have affected the qualitative evaluation of the tool and method (M5); however, participants did provide some negative feedback, mostly regarding specific usability aspects of the tool or clarity of the method. The researchers themselves are experienced goal modelers, but we see our experience as an asset in the design process more than as a limitation.

When measuring novelty & utility, we changed the random order of the group videos for the last three experts such that the two videos for one group were shown sequentially. This could influence results; however, we believe the first two experts could easily match the two videos of each group together (same voices, model expansions). As such, we do not not believe the affect of this change is significant, in fact, we made this change to avoid potentially confusing the experts.

In the summative studies, the content of the goal model was evaluated before and after applying creativity techniques, within the same group. Another possibility would be to have a control group who continue to model without creative interventions. We avoid this design for several reasons. As we've noted, modelers often get "stuck" and lose modeling flow, it would be difficult to force them to model beyond this point. Furthermore, there are many mitigating factors that affect creative performance, e.g., group dynamics, mood, background, iStar skills, and familiarity with the domain – it would have been difficult to effectively design the experiment to isolate creativity activities as the only independent variable. In the current design, we are able to learn about the affects of creative interventions within the same group, a first step into investigating the effectiveness of Creative Leaf.

Construct validity. Creativity is notoriously hard to measure. We have followed standard measurement procedures in terms of fluency and expert opinion, the general standard for creative work in RE. We have also examined flow as an indicator of creativity. Although flow is believed to be a bi-product of creativity [54], it is difficult to measure in a precise way; one can only observe it by looking at the data or by directly observing participants.

We evaluated the content of the goal models through videos, as asking Urban Design experts to evaluate the iStar models directly would be problematic. However, the technical and descriptive quality of each video varied, affecting results. The length also varied, ranging from 2 to 6 minutes.

Our summative study looks at the size of the models, making a link between increased model size and increased completeness. Although we can argue that increasing the number of elements and links in the model can contribute to a more complete model, the concept of completeness in iStar is elusive. When modeling high-level social constructs, one could argue that full completeness is impossible; users are really aiming for an optimal level of completeness to support the task at hand, and that level varies depending on context (e.g., user expertise, models for documentation, sketches for communication). Future work should more carefully evaluate whether the increase in model content triggered by creativity is useful for specific RE-related activities.

The final output of our current creativity process consists of iStar models with ideas integrated via clustering and linking. However, most standard requirements techniques for goal model reasoning and downstream conversion (see Sec. 2.1) expect standard iStar models. Many reasoning techniques for goal models do not pay particular attention to the element type, mainly to the semantics of the links (e.g., [11, 24]), thus it would be possible to apply these procedures to the output of our current method, treating ideas as goals or tasks and evaluating their satisfaction. Transformation techniques are more challenging to apply to our current output. Without understanding the semantics of ideas, its difficult to know how to convert them to a downstream artefact (e.g., textual requirements, element of another model). We can argue the output of the current method is integrated into existing RE methods, using a simple extension; however, further work is needed focusing on convergent creativity, integrating ideas with standard iStar elements.

External validity. We consider whether our results may generalize beyond our study. the participants are all students or post-docs in some technical field; however, their backgrounds were quite diverse, with several participants having extensive industry experience. It is possible that Creative Leaf may be more or less effective in different domains. However, our evaluations have covered four different sample domains, increasing our confidence that the positive affects of the tool apply widely.

7. Related Work

Existing work provides classifications and guidance for creativity in RE. Nguyen et al. consider how elements of creativity (product, process, people, domain, and context) affect the application of creativity to RE [8]. Mahaux et al. examine the changing meaning of creativity in different contexts in order to guide creativity technique selection for an RE project [6]. Further work emphasizes the role of collaboration in creative RE, proposing a list of factors influencing collaborative creativity, e.g., values, and subject matter expertise [55]. In practice, the success of Creative Leaf may be affected by such factors and contexts.

Other work in creative RE introduces and evaluates specific creativity techniques [46, 5, 56]. This work is also complementary, and we could explore the integration of these techniques into Creative Leaf, trying to make an effective map to the underlying goal model. Svensson & Taghavianfar have recently evaluated the effectiveness of varying creativity techniques in the workshop process [57]. While interesting, we are focusing on the tool-supported integration of exploratory creativity with goal modeling, and have not focused specifically on a comparative evaluation of the individual techniques.

Work by Rayasam et al. [45] is the only other work we are aware of exploring goal modeling and creativity. Here, nine participants with an iStar background are asked to use iStar models of a meeting scheduler to generate transformational ideas. They compare generated constructs to existing meeting scheduler constructs from the literature; in this case transformational constructs are those from a new domain (e.g., trading) not appearing in the model or the literature. They found about 1/3 of generated constructs were transformational. The authors observe challenges in order to develop a more systematic process. Comparing this work to the current study raises the question: what is transformational creativity in iStar terms? Is it bringing in elements from a new domain, or making foundational changes to problem boundaries, or both? Future work should look into encorporating ideas from [45] into Creative Leaf, including model constructs from possibly complementary domains, in line with analogical reasoning as a form of creative idea generation [33].

More general work exists in the area of creativity tools. After observing the development of various tools and systems supporting creativity at the IBM T.J. Watson Research Center, Greene provides the following checklist for creativity support tools: support pain-free exploration and experimentation, support engagement with content to promote learning and discovery, support search, retrieval and classification, support (or encourage) mistakes, support domain-specific actions, and should support collaboration, and iteration [58]. Creative Leaf supports some of these desirable behaviors, supporting exploration, engagement with content, search, classification, and iteration. However, further features could be added to support experimentation, mistakes, or collaboration.

8. Conclusions & Future Work

This paper describes several Design Science cycles, producing the Creative Leaf tool and method supporting creativity and goal modeling. The tool and method were developed and validated based on observations of 23 groups with a total of 60 participants. Results from our summative validation study provide us with initial evidence to support the satisfaction of the requirements for Creative Leaf. Our tool allows one to capture the output of creativity techniques in a simple extension to a well-known RE language supporting the use of a wealth of existing RE techniques (e.g., [12, 11]). Through measuring idea generation and qualitative feedback, we have found evidence that the use of goal models in our design does not hinder creativity. The generation of ideas populates goal models with ideas, both creative and otherwise. Participants are able to cluster and link their ideas to the goal model. Future work will focus on supporting the semi-automated process of further integrating these ideas into the model by converting them to iStar constructs. To our knowledge, this is the first work that combines a number of creativity tools and techniques as part of one tool-supported creative RE process. By making a useful and easily accessible online tool, we make creativity techniques more accessible for RE.

This work makes progress in combining the benefits of goal modeling and creativity for RE. In doing so, we have provided an example of how creative ideas can be captured iteratively in a structured modeling language. The general structure of the Creative Leaf tool and method may be emulated for other modeling languages and methods in future work. The first author is currently working on evaluating the use of Creative Leaf as part of video game design.

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